carnivora and herbivora suggest that the habit of living upon a diet consisting exclusively of raw meat entails differences in the types of bacteria that characterize the contents of the large intestine. The occurrence of considerable numbers of spore-bearing organisms in the carnivora points to the presence of anaerobic putrefactive forms in great numbers. The results of subcutaneous inoculations into guinea-pigs bear out this view and indicate that the numbers of organisms capable of producing a hemorrhagic œdema with tissue necrosis, with or without gas-production, are very considerable. Unfortunately, the data pertaining to the biological properties of these pathogenic anaerobes are at present insufficient to permit us to classify them or to say more of their nature than that they are organisms representative of a definite group of putrefactive anaerobes which make butyric acid and hydrogen and exert a peptonizing action upon living tissues. Nevertheless, the observations here recorded are of much interest in relation to the bacterial processes and nutrition of herbivorous[2] as distinguished from carnivorous animals and are significant furthermore for the interpretation of bacterial conditions found in man. The question arises whether the abundant use of meat over a long period of time may not favor the development of much larger numbers of spore-bearing putrefactive anaerobes in the intestinal tract than would be the case were a different type of proteid substituted for meat.

Inquiries made of Dr. Blair, the pathologist at the New York Zoological Park, elicited the fact that while, upon the whole, the carnivorous animals are apt to live somewhat longer than the herbivorous animals of about equal size, the carnivora are much more likely to develop conditions of advanced anæmia in the later years of their lives than is the case with the herbivora. Dr. Blair states that it is usual in the later years of life for the carnivora to show a much diminished volume of blood and at least a moderate fall in the hemoglobin. Instances are stated to be not uncommon in which a pernicious type of anæmia has developed in the carnivora. On the contrary, among the herbivora it is said that pronounced anæmias are very occasional. The examples of severe anæmia encountered among the herbivora were said by Dr. Blair to be in nearly all instances referable to gross animal parasites.

The information now available indicates that man occupies a position between the herbivora and carnivora with respect to the numbers of putrefactive anaerobes that are present in the digestive tract and their proportion to the total number of bacteria. The influence of a purely vegetable diet on the one hand and of a strict meat diet on the other, upon these anaerobes, is much in need of careful investigation.

C. A. HERTER.

[2] Many of the herbivora yielded mixed flora incapable of making gas on dextrose bouillon.

### THE EXCEPTIONAL NATURE AND GENESIS OF THE MISSISSIPPI DELTA.

AT the December meeting of the Cordilleran Section of the American Geological Society, 1905, I read a paper under the above title, an abstract of which, printed on the program, is copied below:

This paper discusses the wholly exceptional materials and form of the lower delta of the Mississippi river, as observed by the writer in 1867 and 1869, and described and discussed in the *American Journal of Science* in 1871. Following out the suggestions of Lyell, and the disputed statement of Humphreys and Abbott that the alluvial deposits of the great river are only of slight depth, the writer investigated the extreme mouths of the Passes, the 'Neck' and the similar minor, bird-foot-like arms projecting beyond. It became apparent that the silty river deposit on these narrow dikes or banks is only superficial, and that their resistance to erosion during overflows is due to their being mainly composed of tough, inerodable 'mudlump clay.' That these mudlumps, observed and described by Lyell, are upheavals of the river bottom, and are formed of such clay as is deposited *outside* of the bar, where the turbid water of the river meets, and is clarified by, the saline sea water. Also, that the mudlump upheavals occur in the *main* outlets or passes of the river, as a direct result of their being the main outlets. No mudlumps then existed in the South Pass, but now that it has been artificially made the main channel, mudlump upheaval has taken, and is taking, place. Mudlump formation is thus

the normal mode of progression of the delta of the main Mississippi.

No such phenomena are known to occur in any other river of the world, hence no other river has such birdfoot mouths. The Mississippi delta should not, therefore, be longer presented as the type of a normal delta, as is done by Russell in his 'Rivers of North America.'

The above paper was not written out for publication, as I then thought it sufficient to have called the attention of geologists to the omission of so exceptional and unique a feature, already elaborately discussed by Sir Charles Lyell in the tenth edition of his 'Elements' (pp. 448–454), and belonging to the principal river of North America. I find the same misconception and omission, however, in Chamberlin and Salisbury's 'Handbook of Geology'; hence it seems desirable to call attention more pointedly, as was suggested to me by Russell, shortly before his death.

Upon the 'correction' of the mouths of the great river, rendered necessary by the peculiar phenomenon of the mudlumps, the government has in the past been obliged to spend many millions. It is still compelled to keep dredgers constantly at work, notwithstanding the fact that the enormous volume of the river has been turned into the single channel of the 'south pass' of the delta. Why does not the scouring action of the current keep this channel permanently open, once for all? And why does not the river, in its twice-annual overflows, break and wash permanent lateral channels through the narrow barriers or levees that jut out into the gulf in bird-foot shape, unlike all other deltas in the world?

A simple examination of the material of which the banks of the 'passes' and of the uprising mudlumps in the channels are composed, answers these questions categorically. The material in both cases is a tough clay, wholly unlike any of the visible sediment carried by the stream; the latter forms only a thin surface layer on the main clay mass bordering and confining the currents of the river, whose scouring action is powerless so long as the clay remains permanently submerged.

Whence this clay, and why should it be brought up forcibly from the channel of the river, of all places the one where the scouring should be most effectively done?

Of this forcing-up there can be no question whatever. Pilots and ship-captains have seen the channel in which they passed to sea a short time before, completely blocked by a mass of tough clay on their return. A ship thus run aground in several feet of water in the evening has found its bow raised out of the water in the morning, requiring several tugs to pull it off backward. For years, tugs with gigantic engines pulled the entering and the sea-going ships through the tough mud, which all the dredging and artificial scouring done by the U. S. River Service could not control. Frequently the mud kept rising as fast as the dredger worked.

Soundings around newly risen mudlumps, and sometimes direct inspection, generally show them to have the form of a rounded bubble, from whose highest point there frequently issue gas bubbles, and sometimes a flow of liquid mud visible even below water. Gas bubbles were also noted whenever the dredgers disturbed a lump in the channel.

When a mudlump rises above tide level, as is frequently the case, there are usually formed on its summit one or several vents, like the craters of mud volcanoes, from which there issues a steady flow of semi-fluid mud, agitated from time to time by gas bubbles; the gas is combustible and, as ascertained by the writer, is such a mixture of marsh gas and carbonic dioxid as is evolved from organic débris in their *first* stages of decay. This gas is undoubtedly derived from the large masses of trees and other vegetable matter carried and buried by the river in its deposits. But its amount, as Lyell correctly estimated, is wholly inadequate to account for the copious and steady flow of fluid mud, which gradually builds up flat cones of solidified material, sometimes attaining the height of fifteen to eighteen feet above tidewater, but more commonly six to ten feet. Usually other craters are formed before the extreme height is reached; or several mud-bubbles coalescing may form a small island with several vents.

The latter in the end are usually choked by solidified mud; and so soon as this happens the work of destruction begins. Sometimes the lump collapses bodily, segments of circular fissures forming all over it, often leaving a small lagoon in the middle; this occurs especially where the material is not a very stiff clay, as in the southwest pass. On the eastern portions of the birdfoot area the destruction of the lumps usually occurs by the waves washing over the *dried* mud of the cones, and bringing it down, to be partly washed away, partly deposited in the intervals between adjacent lumps, connecting them and thus gradually forming a solid, continuous clay dam, on which the river current exerts no sensible eroding effects while it remains submerged.

It is in this way that the narrow bands that bound the outer passes of the Mississippi are formed and maintained, and are made to progress seaward. In other words, *mudlump formation is at present the normal mode of progression of the visible delta into the gulf.*

How far back in time or distance this mode of progression reaches is, of course, unknown at present; but the peculiar, onion-like structure of mudlumps that have risen above the surface and become mud volcanoes, should render this not a difficult problem to solve where sections exist or shall be made within the delta. The peculiar material, so different from any now deposited by the river above its mouth, and which in fact can only have been deposited in slack-water, is enough to distinguish the mudlump formation. It is this same clay that has for ages withstood the impact of the main river-current at the 'head of the passes,' whence the several outlets diverge; the same material forms the narrow banks of the 'neck,' at the head of which, where it diverges from the main delta-mass, forts Jackson and St. Philip are located. Were it otherwise, the narrow barrier separating the neck from Garden-island Bay could not have survived a dozen years of floods; whereas even the channels purposely cut through it by duck-hunters to avoid the long détour through the passes into the bays, have hardly been enlarged in fifty years.

If any more evidence were needed, it is supplied by the existence of an active mud-volcano in the marsh, seven miles above the mouth of the southwest pass, where the writer saw it spouting mudspatters and emitting mudstreams in 1869. This mudlump (then known as Morgan's lump) projected at least eight feet above the tall rushes (*Scirpus lacustris*), and rose, therefore, at least sixteen feet above the level of the marsh.

Sir Charles Lyell ('Elements,' etc., tenth edition, p. 452) inclines to carry the mud-lump-genesis of the delta as far up as New Orleans, from information given him by Col. Sidell, of the River Service, U. S. Topographical Engineers. It should not be difficult to verify this in excavations made at New Orleans; mere borings can not, of course, determine the question.

As to the origin of the mudlumps, Lyell (*loc. cit.*) considers them to be formed on the principle of the 'creeps' so familiar to engineers and miners; he justly ascribes only a secondary part to the gases brought up with the mud, which according to my measurements amount to only one twentieth to one thirtieth of the volume of the material ejected. Lyell says: "The initiatory power may probably be derived from the downward pressure of the gravel, sand and sediment accumulated during the flood season off the various mouths or passes, upon a yielding bottom of fine mud and sand; materials which, as being very fine and impalpable, had long before been carried out farthest from the land." The great mass of river sediment "may well be conceived to exert a downward pressure capable of displacing, squeezing, and forcing up laterally, some parts of the adjoining bottom of the gulf, so as to give rise to new shoals and islands."

There can be no question of the general correctness of Lyell's explanation of this phenomenon, which certainly constitutes the most gigantic example of creep known, and as such should concern the geologist quite as much as the engineer. For why should the Mississippi, of all rivers in the world, *alone* exhibit this remarkable feature and mode of progression? and how, in view of the known average annual progression of the delta into the gulf (338

feet) shall we account for the continued existence of a fluid mud-layer for more than a century, in the case of Morgan's lump—why has not this mud been squeeezed dry into a sheet of clay long ago?

In my view, the entire phenomenon rests upon and is conditioned by the existence of the 'blue delta clay' and 'blue clay bottom' long commented on respectively by the engineers in charge of the river work, and the pilots off the Mississippi mouths. This blue clay constitutes a shelf reaching out about twenty-eight miles beyond the present mouths, where there is a steep descent into deep water. Wherever this clay is exposed along the gulf shore, it contains cypress stumps and other vestiges of swamp origin. It constitutes the main body of the formation which in my Mississippi report of 1860 is doubtfully designated as Coast Pliocene, but to which subsequently, finding it most characteristically developed at Port Hudson, I gave the latter name. Its existence and nature imply that swamp or marsh conditions prevailed to gulfward for nearly thirty miles beyond the present coast line, prior to the advent of the Mississippi River of to-day. Since that time the land has been depressed and reelevated to the extent of some 450 feet at least; but a prior elevation, indicated by stream-gravel beds now 450 feet below sea-level, must have thrown the Mississippi Valley drainage northward toward the Arctic, the divide between the two drainages being very low. This former northward direction of the drainage has been discussed somewhat widely before, by Tight and others, but not, so far as I know, with special reference to the gulf datum-plane and its bordering formations. The lower Mississippi River of to-day is evidently a very 'young' stream.

However that may be, the blue-clay shelf is there, and is practically water-tight and proof against erosion so long as it remains submerged and no gravel is carried by the current. It is in this respect much like the mudlump clay itself. It is constantly found by the sounding-lead outside of the river bar; but before reaching it the lead sinks slowly for some distance in a semifluid mud, which is undistinguishable from that flowing from the mudlump vents. It is manifestly the result of the precipitation of the finest clay and silt when the river water mixes with that of the sea.

In its annual advance of 338 feet to seaward, the sandy bar-material covers this fluid clay much faster than the latter can escape to seaward under the pressure. It is covered by the heavy bar-sand, which from a boat in the shallow water over the bar-crest can be seen being carried rapidly over, shallowing the water outside; while *the deepest water inside the bar is found near the base of its landward slope.* And it is just there, *i. e.,* just *inside* the bar, and not, as Lyell seems to imply, on 'the adjoining bottom of the gulf,' that the rise of mudlumps chiefly takes place; right where the strongest current seems to indicate the best channel for ships to pass. In other words, the current *excavates* the river bed immediately inside the bar, and, relieving the superincumbent pressure, thus enables the mud-bubbles to rise.

It is not clear whether Lyell considers the bar as such to exert the pressure causing the rise; it is, at any rate, difficult to see how the static pressure of a *submerged* bar could cause the same material to rise from ten to fifteen feet above tide-level.[1] But there is no doubt that the weight and wide base of the bar is able to materially obstruct, if not prevent, the squeezing of the semi-fluid mud to seaward, despite a considerable *vis-a-tergo* from landward.

Given a semi-fluid layer of mud on an impervious clay bottom, reaching as far landward as Morgan's lump at least, the source of pressure is not far to seek. The sediment annually deposited on the marsh areas above, with their heavy growth of rushes and other aquatic vegetation, supplies ample weight; and the statement of the pilots that the mudlump springs always become more active when these marshes are overflowed, adds cogency to this explanation. *The vis-a-tergo is the ever-increasing weight of the river-sediments*

[1] The specific gravity of the outflowing mud ranges from a minimum of 1.25 to as much as 1.75.

*proper*, deposited in the marshes above during the twice-annually recurring floods of the great river.

Among the details of the investigation, given in my article above referred to, the following are of interest as corroborative of the above explanation of mudlump phenomena. The microscopic character of the ejected *mud* is precisely that of the mud brought up by the sounding-lead from the seaward slope of the river bar. There is a mixture of fresh-water organisms and débris with marine forms such as foraminifera; but these in the mudlump ejecta are in a macerated condition. The *water* accompanying the outflowing mud, or sometimes welling up clear from old or sandy vents, shows the chemical nature of diluted sea-water subjected to maceration with decaying organic matter. That is to say, its sulphates have been reduced to iron pyrites, which is scattered in shining crystals through the mud, while the water is strongly impregnated with bicarbonates of lime, magnesia and iron, so that it turns turbid on exposure to the air. Taking the common salt as the basis of comparison, the proportion of magnesium chlorid is increased, that of potash decreased; the latter doubtless by the absorption of the base into zeolithic combination.

The *gas* from a vent on the Passe à l'Outre consisted of 86.20 per cent. of marsh gas, 9.41 of carbonic dioxid, and 4.39 of nitrogen. This approximates closely to the average composition of the gas from ordinary swamps. No oxygen was present.

The commercial importance of the formation of mudlumps is well illustrated in the history of the several outlets or passes during historic times. The earliest navigation from the gulf to New Orleans was almost wholly through the 'Passe à l'Outre,' the most northerly of the mouths, whose very name indicates its chief importance as the outlet for deep-sea vessels destined for 'outre-mer'; with the northeast pass, it remained the main outlet in use even to the first third of the past century. Then it became so contracted and shallowed by mudlumps that the northeast and southeast passes were for a while the main channels used by vessels; but these also being soon heavily obstructed by lumps, and the south pass being too narrow and shallow for deep-sea ships, the southwest pass was, during the greater part of the past century, the main outlet for navigation. Its channel being very wide and its deposits more sandy by reason of its being most nearly in line with the main river at the head of the passes, its use involved the additional difficulty of shifting sand bars. To keep a navigable channel through these and the copious mudlump formations was an endless task, and cost the government millions; besides necessitating the use of enormously powerful tugs for the shipping. After many unsuccessful attempts for permanent relief, all of which were frustrated by the rise of mudlumps, came Eads's proposition to turn the river into the south pass, the mouth of which was then free from mudlumps. While this matter was before congress, the writer called Eads's attention to the almost certainty that whenever the south pass should be made the main outlet, mudlump upheaval would surely occur. Eads replied that he hoped that the increased velocity of the current in the narrow channel inclosed by his jetties would keep it scoured out to a much greater extent than the shallow southwest pass had been, and that at any rate it should be tried as an *ultima ratio*, and allowed to go unchallenged. To this, of course, I agreed.

The event has in the end justified both Eads's and my anticipation. Not many years after the completion of the jetties and wing-dams, mudlump upheaval began inside of the south pass bar; but the watchful activity of dredgers, together with the scouring action of the full river current, are successfully keeping the channel in navigable condition, at very much less current expense, and much more effectually, than could ever be accomplished in the southwest pass.

Taken altogether, these unique phenomena characterizing the formation and progression of the Mississippi delta seem to be of sufficient importance, both theoretical and practical, to render their omission from handbooks of American geology and hydrology hardly excusable. It is expected of those who write such treatises that they should acquaint them-

selves with all previous literature on the same subjects; but notwithstanding the elaborate bibliographies now so commonly appended to papers on special topics, the crediting and utilization of the more remote publications seems in danger of falling into innocuous desuetude. E. W. HILGARD.

UNIVERSITY OF CALIFORNIA,
December, 1906.

## CURRENT NOTES ON METEOROLOGY.

### BLUE HILL OBSERVATORY.

VOL. LVIII., Part II., of the *Annals of the Harvard College Observatory* contains 'Observations and Investigations made at the Blue Hill Meteorological Observatory in the Years 1903 and 1904.' From the introduction we learn that Mr. H. H. Clayton, well known as one of the foremost meteorological investigators in the world, has completed twenty years of service at Blue Hill, and that Mr. S. P. Fergusson, who, by his skill as a mechanician and his general ability along many lines of meteorological inquiry has contributed largely to the success of the Blue Hill work, has completed eighteen years of service. The introduction also contains a review of the principal work done at Blue Hill in the twenty years since its opening, but as readers of SCIENCE are familiar with much of this, we do not summarize here. Mr. A. Lawrence Rotch, the founder of the observatory, without whose untiring devotion to his science and unfailing readiness to assume the increasing financial burden of maintaining this institution the United States would occupy a far less prominent place in meteorological advancement, may well look back on the past twenty years of work at Blue Hill with pride and satisfaction. American men of science can have but one hope and wish in connection with the Blue Hill Observatory: that its next twenty years may be as fruitful in results as the last twenty have been.

### THUNDER-STORMS AND THE MOON.

MUCH time has been spent by various investigators in the attempt to show some relation between the occurrence of thunder-storms and the phases of the moon. The latest contribution to this discussion comes from C. W. Hissink, of Zutphen, who in the September number of 'Hemel en Dampkring' presents the results of a study of thunderstorm days in Holland for the period 1883–1903. The means for these years show so complete an agreement for different phases of the moon that there can be no question that no lunar influence is shown. Evidently the supposed connection between moon and thunder-storms depends for the results obtained upon the period which any investigator uses, and upon the length of the series of observations. When a long series of observations is available, no lunar influence is, on the whole, manifest.

### LANTERN SLIDES ILLUSTRATING CLIMATE.

WE note the publication, by the Diagram Company, of New Malden, Surrey, England, of the seventh issue of 'The Diagram Series,' designed by B. B. Dickinson, assistant master at Rugby, and A. W. Andrews, extension lecturer. This series comprises a considerable number of lantern slides illustrating the climate of the world as a whole, and of the separate continents. Among these we observe charts of isotherms, isobars, winds, ocean currents and rainfall. It is encouraging to see the rapid increase in the demand for such teaching materials in meteorology and climatology for use in colleges and schools.

R. DEC. WARD.

## NOTES ON ENTOMOLOGY.

A MOST interesting and attractive paper is that of Arnold Pictet,[1] on the influence of food and humidity on Lepidoptera. A great number of experiments were made by the author on the larvæ of twenty-one different species of Lepidoptera, among them the gipsy and brown-tail moths. His results show that changing the usual food is apt to cause variation in adults. A food difficult of assimilation hinders the growth of the caterpillar and lengthens larval life; in consequence the pupal

[1] 'Influence de l'alimentation et de l'humidité sur la variation des papillons,' *Mém. Soc. Physique et d'Hist. Nat. de Geneve*, Vol. **35**, pp. 45–127, 4 pl., 1905.